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(56) Documents Cited
GB 2235819 A EP 0638918 A US 4721885 A

(58) Field of Search
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INT CL^6 **G09F 9/313 , H01J**
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(54) **Displays**

(57) A display comprises a matrix of cells (2) each having an anode 20 and a cathode 21 which is in the form of a field emitter, e.g. a cone or a layer of diamond. The cells contain an ionizable gas such as xenon or a mixture of xenon with other rare gases, and include fluorescent layer 18. Primary electrons emitted by the cathode excite the gas by collision in a weakly ionized plasma. Neutral atoms are then excited by the plasma to radiate VUV which is converted to red, blue or green light by the fluorescent layer. The cells may also include gate electrodes, and are connected to a conventional address and drive unit.

Fig.2.

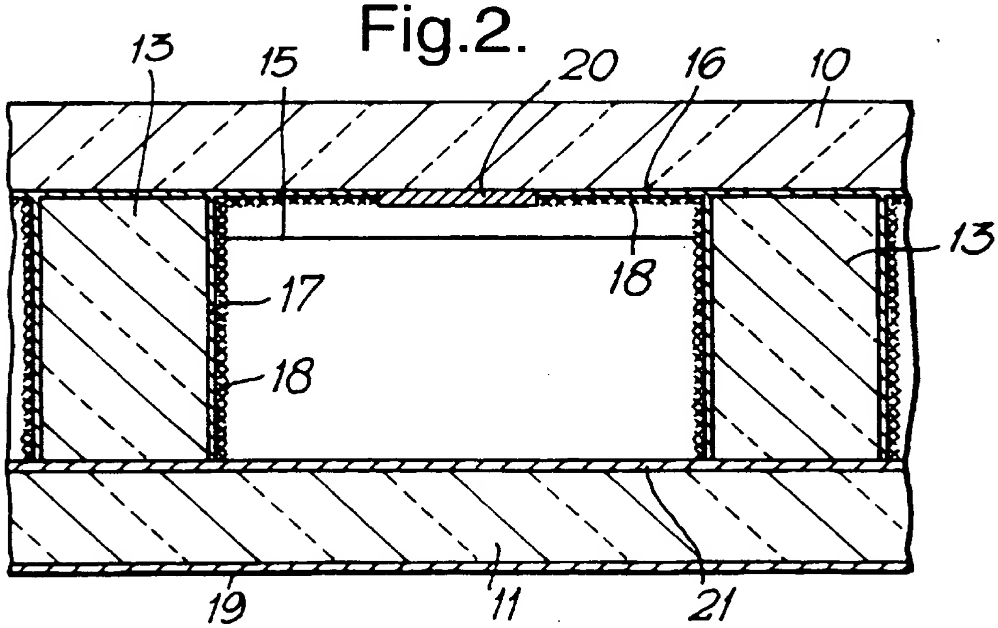

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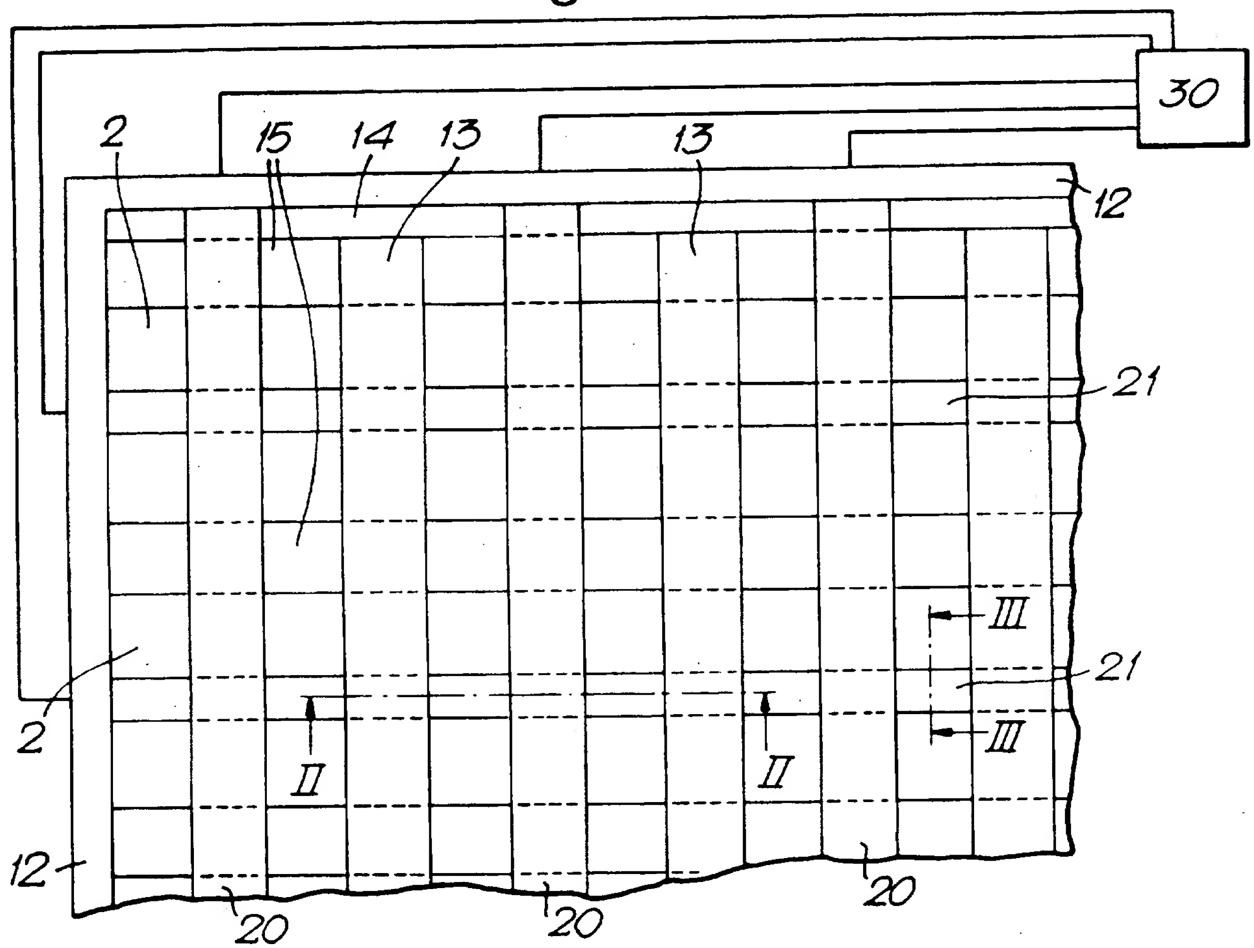
Fig.1.


30
2
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21
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Fig.2.

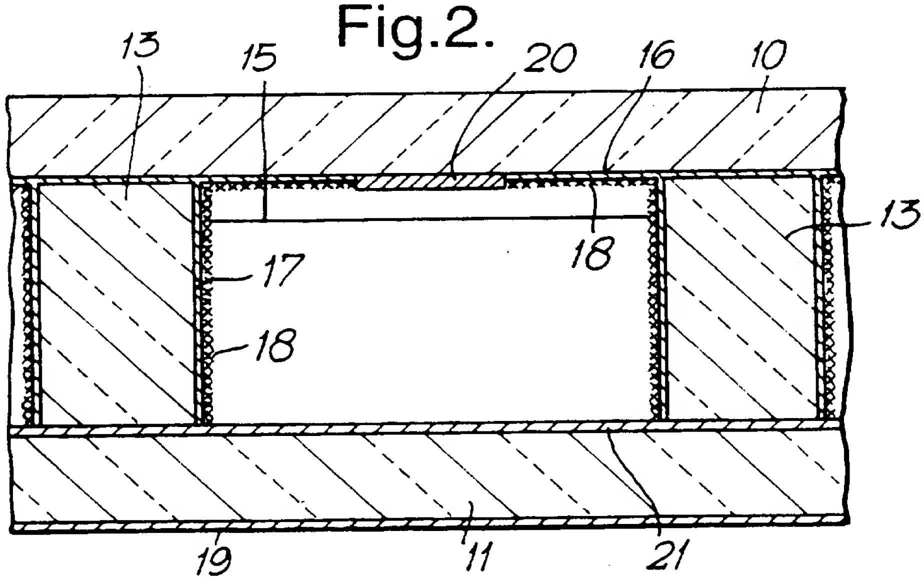
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Fig.3.

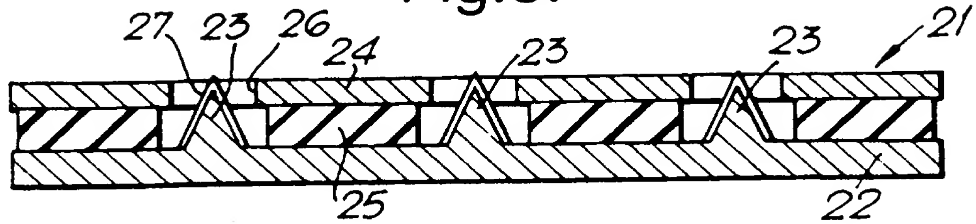


Fig.4.

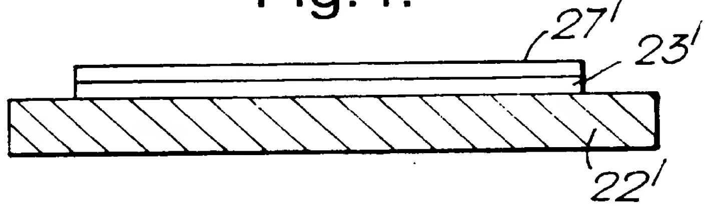


Fig.5.

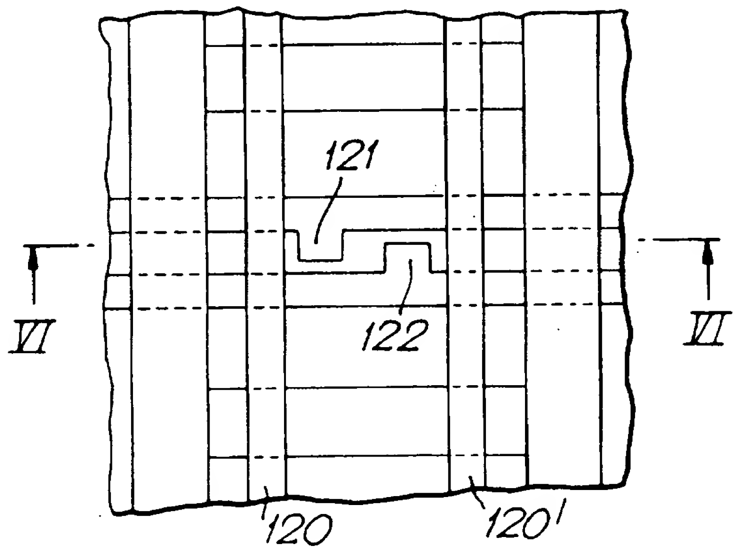


Fig.6.

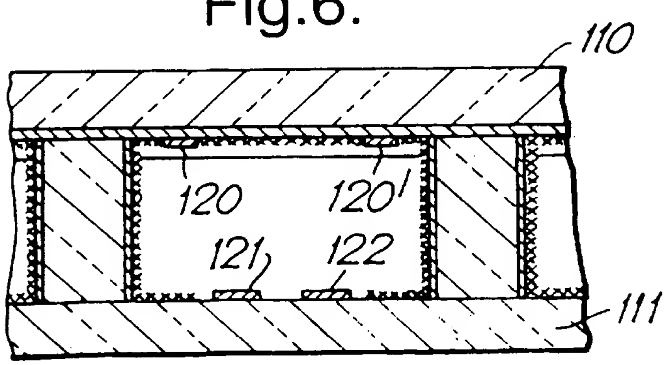


Fig.7.

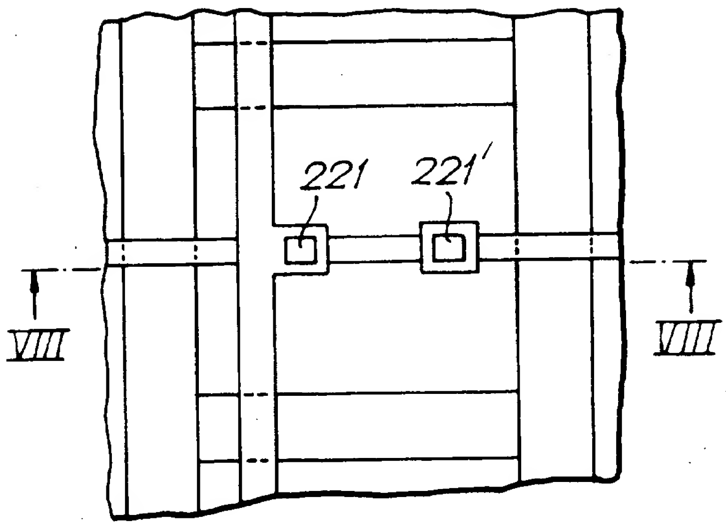
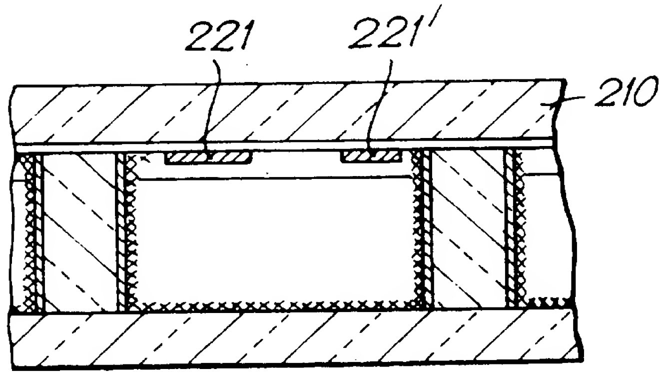


Fig.8.



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DISPLAYS

This invention relates to displays such as of planar form.

Plasma display panels can give a high resolution colour display and be relatively compact. Present plasma display panels, however, are relatively inefficient, with luminous efficiencies being below 1 lm/W, which is considerably less than that of a CRT of about 4 lm/W. Also, plasma displays need high striking voltages, which can only be produced by expensive driver electronics.

Existing plasma displays operate in the following way. The high voltage between the cathode and anode produces a cathode fall region in front of the cathode through which plasma ions are accelerated towards the cathode. The ions impact the surface of the cathode and their energy is dissipated into heat and into the production of secondary electrons, the yield of which is proportional to the work function of the cathode metal. The secondary electrons drift through the gas plasma making ionising collisions with the gas atoms and thereby sustaining the gas plasma. The secondary electrons also excite neutral atoms to resonance states, the gas mixture being chosen to contain gas species with resonant levels in the violet to ultra-violet (VUV) range of the spectrum so that, as the atoms fall back to their neutral state they give up their energy as radiation in the VUV range. Phosphors in the display convert the VUV to visible light through the mechanism of photoluminescence.

The ion bombardment of the metal cathode needed to sustain a glow discharge does not generate secondary electrons efficiently. The yield from a typical low work function surface is less than 10%.

Furthermore, where secondary emission is used to generate charge carriers in a small cell, the number of carriers is depleted quickly because of high diffusion losses to the walls of the cell.

Proposals have also been made for planar displays incorporating a matrix of field emitters, such emitters being of the class of thin film structures incorporating microscopic points, edges or discontinuities, which give rise to room temperature free electron emission when a gate or electrode in close proximity is charged to a positive voltage, generally in the range of 10 to 100V. The emitted electrons are then accelerated towards a phosphor layer, where they cause cathodoluminescence, the same light producing mechanism as in a CRT.

Phosphors, however, have a relatively low efficiency (about 1%) at low cathodoluminescent voltages, of about 400 volts, employed so far. Attempts to increase efficiency by increasing anode voltage to kilovolt levels have met with problems in fabricating displays capable of operating at these voltages.

It is an object of the present invention to provide an improved form of radiation-emitting display.

According to one aspect of the present invention there is provided a radiation-emitting display comprising a sealed assembly containing an ionizable gas, a fluorescent layer on a part of the assembly arranged to convert radiation emitted in the assembly to visible radiation, at least one first electrode arranged as an anode and at least one second electrode arranged as a cathode, the cathode having a field-emitting source that causes ionization of the gas in the assembly and the production of radiation.

The field-emitting source is preferably provided by a plurality of cones, which may be of silicon and may have a surface layer of diamond. The display may include a gate layer adjacent the field-emitting source. The gate layer may have a plurality of apertures, the display having a plurality of sources and the sources projecting into the apertures. Alternatively, the field-emitting source may be provided by a material with a negative electron affinity, such as diamond. The assembly preferably includes a plurality of cells, a cathode and anode being exposed within each cell such that gas can be ionized in each cell. The cells are preferably separated from one another by a plurality of walls and barriers extending orthogonal to the walls. The walls and barriers are preferably opaque to radiation so that radiation produced in one cell is substantially prevented from entering an adjacent cell. Different ones of the cells may have different fluorescent layers that fluoresce with different colours, such as red, green and blue. The assembly preferably has an upper plate and a lower plate, the cathode being formed on the lower plate, and the upper plate being transparent to visible radiation and reflective of UV and VUV radiation.

According to another aspect of the present invention there is provided a radiation-emitting display comprising: a sealed assembly with an upper plate transparent to visible radiation, a lower plate and a peripheral wall; an ionizable gas in the assembly; a plurality of internal walls opaque to radiation; a plurality of barriers opaque to radiation extending orthogonal to the internal walls so as to divide the assembly into a plurality of cells; a fluorescent layer on the internal walls and barriers to convert radiation emitted in the cells to visible radiation; at least one first electrode arranged as an anode in each cell; and at least one second electrode arranged as a cathode in each cell, the cathodes providing a field-emitting source in each cell arranged to cause ionization of the gas and the production of

radiation, such that by energizing appropriate ones of the first and second electrodes, visible radiation can be produced in any one of the cells.

The or each cathode preferably extends along the lower plate and the or each anode preferably extends along the upper plate. The display may include a pair of ac electrodes, a cathode and a gate electrode, the gate electrode being located adjacent the cathode such that a voltage applied between the cathode and the gate electrode causes pre-ionization enabling a voltage between the ac electrodes to ignite a plasma. The ac electrodes are preferably on one plate and the cathode and gate electrodes are on the other plate. The assembly preferably has an internal pressure in the range 250-500 torr.

A display according to the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1	is a plan view of a part of the display;
Figure 2	is a sectional side elevation of the display along the line II-II, to a larger scale;
Figure 3	is a sectional side elevation view of a field-emitter assembly of the display along the line III-III of Figure 1;
Figure 4	is a sectional side elevation view of an alternative field-emitter assembly;
Figure 5	is a plan view of a part of an alternative display;
Figure 6	is a sectional side elevation along the line VI-VI of Figure 5;

Figure 7 is a plan view of another alternative display; and

Figure 8 is a sectional side elevation along the line VIII-VIII of Figure 7.

With reference to Figures 1 to 3, the display has an upper plate 10 of a dielectric material, such as glass, which is transparent to light in the visible part of the spectrum. The plate 10 is about 1mm thick. A lower plate 11, preferably made from the same material, or from a material with a similar thermal expansion, extends parallel to the upper plate 10. The upper plate 10 is supported above the lower plate 11 by peripheral walls 12, which may be formed by etching from the lower plate. The walls 12 are typically about 100μm high but may be lower than this. The walls 12 are sealed to the underside of the upper plate 10 to form an enclosed assembly. Internally of the assembly, the upper plate 10 is supported by parallel walls 13 equally spaced from one another across the display to divide the display into parallel columns. The walls 13 do not extend completely across the display but are separated from the peripheral walls 12 along one side by a narrow channel 14 that enables gas communication between the different columns. The display is also divided into parallel rows by a number of parallel barriers 15, which extend orthogonally to the walls 13. The barriers 15 are lower than the walls 13 so that there is a small gap between the top of the barriers and the underside of the upper plate 10 (as shown in Figure 2). This enables gas to flow along the columns of the display. The walls 13 and barriers 15 divide the cell into individual pixels or cells 2, each about 0.3mm square.

The lower surface of the upper plate 10 is coated with a dielectric layer 16 that reflects radiation in the UV and VUV part of the spectrum but is transparent to visible light from blue through to red. The walls 13 and barriers 15 are preferably coated with an aluminium layer 17, which reflects radiation in the UV and visible part of the spectrum, so that radiation generated in one cell 2 is not transmitted to adjacent cells. The walls 13 and barriers 15 may be made opaque to radiation in other ways. On top of the layer 17 there is a fluorescent layer 18 of

phosphor material. The fluorescent layer 18 is of one of three different phosphors that emit radiation in the red, blue or green parts of the spectrum, with cells 2 along each row and column being arranged: red, blue, green. The fluorescent layer 18 continues over the underside of the upper plate 10 and over the upper side of the lower plate 11 in the regions of the plates not occupied by the display electrodes 20 and 21.

The upper electrodes 20 are anodes and are provided by parallel conductive tracks extending centrally along the length of each column on the underside of the upper plate 10. Each anode track 20 is preferably formed by a layer of conductive material, such as tin oxide, indium tin oxide or aluminium, thin enough to be transparent to visible radiation.

The lower electrodes 21 are cathode tracks on the upper surface of the lower plate 11 extending orthogonally to the anode tracks 20, and are shown in greater detail in Figure 3. Each cathode track is a thin film field-emitter comprising a strip 22 of silicon or metal, such as molybdenum, with a number of vertical cones 23. The cones are formed by deposition, etching, machining or any other technique, and are typically about 1-2 μm high. A conductive gate layer 24 is located adjacent the cones 23, being separated from the silicon layer 22 by an insulating layer 25. A gate layer is not always necessary, such as, when there is close spacing between the anode and cathode. The cones 23 project into and are exposed through apertures 26 in the gate layer 24; they may be left as uncoated molybdenum or coated with a second material to improve emissive or other properties, such as a semiconducting polycrystalline diamond film or an amorphic diamond film 27. The tips of the cones 23 function as microscopic formations for the emission of free electrons. The diamond film exhibits a negative electron affinity and a lower work function than the cone material, which increases the emissivity of the cones.

An alternative field emitting structure is shown in Figure 4. In this structure, the substrate 22' is patterned with a metal electrode layer 23' and with a semiconducting diamond film layer 27'. The surface of the field emitter is smooth, the field-emitting property being

achieved solely because of the field-emitting nature of the diamond material. Other materials with a negative electron affinity could be used. There is no gate layer.

The anode tracks 20 and cathode tracks 21 extend to a conventional address and drive unit 30. Because the anode and cathode tracks 20 and 21 are exposed within each cell, a voltage can be applied across any one of the cells 2 by energizing the appropriate combination of anode and cathode.

The display and its cells 2 are filled with an inert gas such as Xe or a mixture of gases such as Ar-Xe, Ne-Xe, Ne-Ar-Xe. Xe generates intense bursts of radiation of 157nm (that is, in the VUV range) when excited in a gas discharge.

A relatively low voltage of between 30 and 100V is applied across the selected cell 2, which operates as a Townsend discharge device. The field-emission matrix generates primary electrons, which excite the gas by collision in a weakly ionized plasma. Neutral atoms are then excited by the plasma particles to radiate VUV. The VUV photons impinge on the phosphor layer 18 causing it to fluoresce at visible wavelengths, either in the red, green or blue parts of the spectrum. The mechanism by which visible radiation is generated is, therefore, completely different from that of previous displays employing field-emitters where the energy of the electrons generated is used to produce cathodoluminescence by direct collision of the electrons with a phosphor layer.

The reflective layer 16 on the upper plate 10, and the aluminium layer 17 on the walls 13 and barriers 15 help confine the VUV radiation within the cell 2 so as to increase the probability of photoluminescent conversion in the phosphor layer 18. The lower surface of the lower plate 11 may also have a reflective layer 19 that reflects both VUV and visible radiation upwardly into the overlying cell 2. The cell configurations shown in the diagrams are not necessarily optimum for the highest coupling efficiency between the VUV radiation and the phosphor coating. Other configurations, which take advantage of the field emitter plasma

initiation and structure within the cell cavity may be determined empirically to improve overall cell light conversion efficiency.

The display of the present invention requires only a low initiation voltage and, therefore, requires only low voltage driver circuits, which can be of lower cost, more compact, lighter and with lower heat dissipation than in conventional plasma displays. The display can use gas or gas mixtures optimized for a high UV output, such as including xenon. Because the display can operate at relatively high pressure (in the range 250-500 torr) compared with conventional discharge displays, this simplifies the construction of the display, in that it is not essential to provide a structure and seals capable of withstanding high vacuum. The efficiency of the display in converting electrical energy into visible energy can be very high. Also, there is no warm-up delay as in conventional cold cathode displays, so the display is essentially instantaneous, making it suitable for displaying rapidly changing images.

Various alternative displays are possible, such as shown in Figures 5 and 6. In this display, the upper plate 110 has two electrodes 120 and 120', which are ac electrodes such that one is an anode while the other is a cathode. A field-emitter cathode 121 on the lower plate 111 is located adjacent a gate electrode 122. The gated field-emitter pre-ionizes the gas to enable the ac electrodes to ignite a plasma at a lower strike voltage than would otherwise be required. The ac electrodes could be driven at a voltage just below what is sufficient to strike a plasma, so that the plasma is produced when the field-emitter is energized. The gated field-emitter could also be used to sustain higher current densities in a plasma cell, for brighter pixels or grey scale.

In the arrangement of Figures 7 and 8, two field-emitter electrodes 221 and 221' are mounted on the upper plate 210 and are operated as ac electrodes such that one acts as an anode while the other acts as a field-emitter cathode.

CLAIMS

1. A radiation-emitting display comprising a sealed assembly containing an ionizable gas, a fluorescent layer on a part of the assembly arranged to convert radiation emitted in the assembly to visible radiation, at least one first electrode arranged as an anode and at least one second electrode arranged as a cathode, wherein the cathode has a field-emitting source that causes ionization of the gas in the assembly and the production of radiation.

2. A display according to Claim 1, wherein the field-emitting source is provided by a plurality of cones.

3. A display according to Claim 2, wherein the cones have a surface of diamond.

4. A display according to Claim 2 or 3, wherein the cones are of silicon.

5. A display according to any one of the preceding claims, including a gate layer adjacent the field-emitting structures.

6. A display according to Claim 5, wherein the gate layer has a plurality of apertures into which the field-emitting structures project.

7. A display according to Claim 1, wherein the field-emitting source is provided by a material with a negative electron affinity.

8. A display according to Claim 7, wherein the material is diamond.

9. A display according to any one of the preceding claims, wherein the assembly includes a plurality of cells, and wherein a cathode and anode is exposed within each cell such that gas can be ionized in each said cell.

10. A display according to Claim 9, wherein the cells are separated from one another by a plurality of walls and a plurality of barriers extending orthogonal to the walls.

11. A display according to Claim 10, wherein the walls and barriers are opaque to radiation so that radiation produced in one cell is substantially prevented from entering an adjacent cell.

12. A display according to any one of Claims 9 to 11, wherein different ones of the cells have different fluorescent layers that fluoresce with different colours.

13. A display according to Claim 12, wherein different ones of the cells have fluorescent layers that fluoresce with red, green and blue colours.

14. A display according to any one of the preceding claims, wherein the assembly has an upper plate and a lower plate, wherein the cathode is formed on the lower plate, and wherein the upper plate is transparent to visible radiation and reflective of UV and VUV radiation.

15. A radiation-emitting display comprising: a sealed assembly with an upper plate transparent to visible radiation, a lower plate and a peripheral wall; an ionizable gas in the assembly; a plurality of internal walls opaque to radiation; a plurality of barriers opaque to radiation extending orthogonal to the internal walls so as to divide the assembly into a plurality of cells; a fluorescent layer on the internal walls and barriers to convert radiation emitted in the cells to visible radiation; at least one first electrode arranged as an anode in each cell; and at least one second electrode arranged as a cathode in each cell; wherein the cathodes provide a field-emitting source in each cell arranged to cause ionization of the gas and the production of radiation, such that by energizing appropriate ones of the first and second electrodes, visible radiation can be produced in any one of the cells.

16. A display according to Claim 14 or 15, wherein the or each cathode extends along the lower plate and the or each anode extends along the upper plate.

17. A display according to any one of the preceding claims, including a pair of ac electrodes, a cathode and a gate electrode, wherein the gate electrode is located adjacent the cathode such that a voltage applied between the cathode and the gate

electrode causes pre-ionization enabling a voltage between the ac electrodes to ignite a plasma.

18. A display according to Claim 17 and any one of Claims 14 to 16, wherein the ac electrodes are on one plate and the cathode and gate electrodes are on the other plate.

19. A display according to any one of the preceding claims, wherein the assembly has an internal pressure in the range 250-500 torr.

20. A display substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

21. A display substantially as hereinbefore described with reference to Figures 1 to 3 as modified by Figure 4 of the accompanying drawings.

22. A display substantially as hereinbefore described with reference to Figures 1 to 3, as modified by Figures 5 and 6 of the accompanying drawings.

23. A display substantially as hereinbefore described with reference to Figures 1 to 3, as modified by Figures 7 and 8 of the accompanying drawings.

24. Any novel feature or combination of features as hereinbefore described.

The Patent Office

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Application No: GB 9600173.0
Claims searched: all

Examiner: Martyn Dixon
Date of search: 20 February 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H1D (DAB6,DABXA,DBT1,DBT2)

Int Cl (Ed.6): H01J: G09F (9/313)

Other: online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2235819 A	(Cathodeon) see e.g. fig 2 and page 6, line 18 et seq	1,2,4-6,9-11
X,P	EP 0638918 A	(Science Applications International) see figs 2-4 especially	1,2 at least
Y	US 4721885 A	(SRI)	1,2,4-6,9-11

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		